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Optimized Histogram Based Contrast Limited Enhancement for Mammogram Images

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***Abstract*— Detection of breast cancer in its early stage is very important in the field of medicine. Optimal Contrast Enhancement is essential for the detection of mass and micro calcification in mammogram images. The standard histogram equalization is effective and simple method for contrast enhancement but for medical images most of the time it produces excessive contrast enhancement due to lack of control for the level of enhancement. In this paper image enhancement is considered as an optimization problem and an optimization technique based on entropy and edge information of the image is presented. The enhancement function used in the paper is Contrast Limited Adaptive Histogram Equalization (CLAHE) based on local contrast modification (LCM). Its enhancement potential is tested by sobel operator for the detection of microcalcification. Results are compared with other enhancement techniques such as Histogram Equalization, Unsharp Masking and CLAHE.**

***Index Terms* — Optimization, Enhancement parameter, Parameter Tuning, Histogram Equalization, Local Contrast Enhancement, CLAHE, Objective Criterion**

I. Introduction

In the present medical scenario detection of breast cancer in its early stage is a very immense challenge. Even with the advancement in medical technology it is complex to detect cancerous cells in its premature stage. Annual report on status of cancer reveals that one in eight women develops cancer in their lifetime and it is one of the major causes of death for woman in United States [1]. Breast Health Resource of Avon Foundation says that approximately every 3 minutes a woman is diagnosed with breast cancer and approximately every 12 minutes breast cancer claims another life. Breast cancer impacts over 240,000 new patients a year in the United States alone. As breast cancer is not preventable early detection is necessary [2]. This is especially important because of the high incidence of the disease as well as the absence of the identifiable risk factors.

There are many methods for detection of breast cancer. Mammography is one of the primary methods in the detection of breast cancer. It is very effective method of finding breast diseases. Even with this effective method over 10 percent of the cancerous lesions are not detected [3]. This is because the images obtained using capturing device exhibit several defects such as non-uniform illumination, sampling noise, low contrast etc. So preprocessing of such defected images plays an important role in an image processing system. The pre-processing operations are image enhancement for improving the image details, thresholding to reduce gray scale, filtering for noise reduction, segmentation to separate various components in the image etc [4]. Of these operations, image enhancement plays an important role in the pre-processing phase of digital image processing.

Numerous algorithms have been developed for image enhancement in medical field and various techniques has been developed which improved the image quality to a certain extend [5].The major limitations of various image enhancement schemes are difficulty in highlight the very finer details of the image and lack of means to adjust the parameters. The aim of our image enhancement algorithm is to get finer details of an image and highlight the useful information that is not clearly visible in the original image.

II. Related Works

Histogram Equalization (HE) is one of the popular methods for contrast enhancement which modify the gray level histogram of an image to a uniform distribution [4]. But in many cases it produces over enhancement in output image and loss of local information which leads to insufficient medical details during diagnosis.To overcome these drawbacks, many variants of HE have been proposed [5-8].

In medical imaging such as mammogram image enhancement local contrast are more important than global contrast. In such type of applications Global Histogram Equalization (GHE) is insufficient because it cannot deal with local features of original image due to its global nature. Adaptive Histogram Equalization (AHE) method will perform throughout all pixels in the entire image and maps gray level using local histograms, but it takes more time [5]. Pizer has proposed AHE in which the input image is divided into blocks and then the mapping functions are computed for those blocks using CLAHE [7]. M.Sundaram has proposed a method for image enhancement based on Histogram Modification and CLAHE which uses an enhancement parameter for adjusting the contrast of the image. The enhancement parameter is selecting manually in this work [9].Youfu Li and Ting Yang proposed a new form of histogram for image enhancement. In this method the input image is first divided into several equal-sized regions according to the intensity of gradients, their corresponding statistical values of gray levels are then modified respectively, and finally the processed histogram for the whole image is obtained by

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the summation of all the weighted values of regions [11]. N.Arumugam presented contrast enhancement for the detection of micro-calcification of mammograms based on the Histogram Modified Contrast Limited Adaptive Histogram Equalization. The Histogram Modified Contrast Limited Adaptive Histogram Equalization provides an option for adjusting the level of contrast enhancement, which in turn gives the resultant image a strong contrast and brings the local details for more relevant interpretation [10]. Apurba Gorai proposed Particle swarm optimization for gray level image enhancement. In this method image enhancement is considered as optimization problem and PSO is used to solve it. The image enhancement is done by maximizing the information content of enhanced image with intensity transformation [12]. Gao Qinqing proposed an image enhancement technique based on improved PSO algorithm. In this method, an improved PSO algorithm is used to solve the optimization for image enhancement. The parameterized transformation function used in this method uses both global and local information of the image [13]. Many research works have been done on mammograms for its contrast enhancement and identification of image features like cluster of microcalcification and masses [14-17]. PritishPal have proposed wavelet based information for retrieval and classification of mammographic images [18]. Ecomopouslos et al proposed iterated function systems which is not suitable for mammogram image enhancement in the sense that it gives more irrelevant information as artifacts [19].

The standard CLAHE method produces over enhancement which results in the loss of some local information [9]. In order to overcome this limitation we have proposed LCM-CLAHE. This method will produce optimal contrast without losing any local information of the mammogram image which is most important for detection of breast cancer. The proposed method LCM-CLAHE consists of two stages of processing to increase the potentiality of contrast enhancement and to preserve the local details in the images. The LCM-CLAHE method heavily depends on the selection of enhancement parameter. So to make the selection of the Enhancement parameter automatic an Optimization technique is also added. The details of the proposed method are presented in the next section.

III. Materials and Methods

A. Histogram Equalization

A Histogram is a graphical representation of the number of pixels in an image plotted for each different intensity value found in that image. The histogram helps the viewer to judge the entire lightness distribution of a specific image. In the context of image processing the process of adjusting the contrast of an image is called Histogram Equalization. This is applied for increasing the global contrast of many images. However using HE may result in increasing the contrast of background noise as well as decreasing the usable signal. AHE and CLAHE are two generalization of HE which uses multiple histograms.

B. Adaptive Histogram Equalization

AHE computes several histograms for distinct section of the image and uses them to redistribute the lightness values of the image. So it is suitable for improving the local contrast of an image and bringing out noise detail. The main disadvantage of AHE is a tendency to over amplify noise in relatively homogenous regions of an image.

C. CLAHE

CLAHE is a special type of adaptive histogram equalization. It limits the maximum contrast adjustment that can be made to any local histogram and this limitation is useful so that the resulting image does not become too noisy. CLAHE is explained in detail in section *F*

D. Proposed Method

CLAHE is a variant of AHE which reduces the noise amplification. But using CLAHE also we have found that it is also not so suitable for mammogram images of very fine details. In Histogram Modified (HM)-CLAHE the author have proposed global modification of histogram along with CLAHE [10].But in mammogram images local details are more important than global details for the detection of cancerous cells. So in the proposed method we have used a local contrast enhancement (LCM) to highlight the fine details hidden in the mammogram image and an enhancement parameter to control the level of enhancement along with standard CLAHE and an Optimization technique to tune the enhancement parameter. So incorporating LCM with CLAHE and Optimization technique produces an optimal contrast enhancement with all local information of mammogram images which may not be obtained using Standard CLAHE.

The Figure 1 shows the steps involved in the proposed image enhancement method. First we read the input mammogram image and then initialize the Enhancement parameter and pbest value. The pbest is best value for enhancement parameter.Then we call the enhancement function for the pbest and its fitness function (objective function).The enhancement function include LCM and CLAHE and Objective function is explained in the section *G*. Then enhancement function for the enhancement parameter p and its fitness function are calculated. After that Fitness value of f (Ep) which is the fitness value calculated for Enhancement parameter using Objective criteria and f (Epbest) which is the fitness value calculated for pbest using Objective criteria is compared. If f (Ep) is greater than f (Epbest), then p is assigned to pbest and its fitness value. The enhancement parameter p is incremented and again the steps are repeated till Enhancement parameter become one. Finally the optimal value for the enhancement parameter will be in the pbest and we will obtain the enhanced image for pbest value.

E. Local Contrast Modification (LCM)

In local contrast enhancement we first calculate the mean and standard deviation and initialize the enhancement parameter range. The transformation function can formulated as given below

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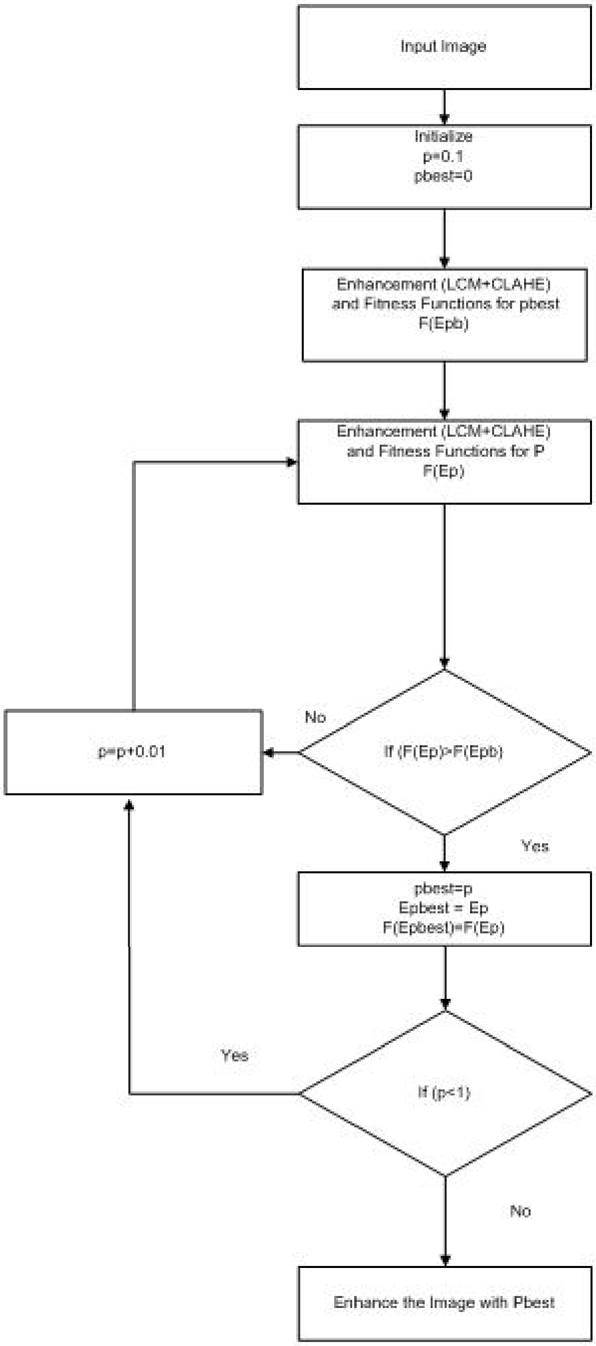

Fig. 1. Proposed Enhancement method flow diagram

$$T = \frac{E \ . M}{\sigma} \tag{1}$$

$$g = T * (f - m) + m \tag{2}$$

where g and f are LCM enhanced and input image respectively and E is the enhancement parameter, M is the global mean of the input image, m is the local mean and ó is the local standard deviation, E is a positive constant and value is in between 0 and 1. The expression for local mean and standard deviation for the user defined window is computed as follows

$$m(x, y) = \frac{1}{n \times n} \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} f(x, y) \tag{3}$$

$$\sigma = \sqrt{\frac{1}{n \times n} \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} \left(f(x, y) - m(x, y) \right)^2} \tag{4}$$

F. CLAHE (Contrast Limited Adaptive Histogram Equalization)

The second stage in the proposed method is applying CLAHE on the local contrast modified mammogram image. CLAHE has shown good result in contrast enhancement of medical images. It has good tractability in choosing local histogram mapping function. The CLAHE method divides the image into appropriate regions and applies histogram equalization to them. This method modiûes the intensity values of the image employing a nonlinear methodology in order to maximize the contrast for all pixels of the image. The clipping level selection of the histogram reduces the undesired noise amplification. The clipped pixels are redistributed to each gray level. The new histogram is different from the normal histogram, because intensity of each pixel is limited by user-selectable maximum. Thus CLAHE method can limit the noise enhancement

G.. Objective Criterion

The quality of an enhanced image is measured automatically by employing an efficient objective criterion [21, 22]. The objective function used in this work is based on the performance measures such as entropy, sum of edge intensities and number of edge pixels [12, 23]. It can be observed that optimal enhanced image has more number of edge pixels and higher intensity value at the edges as compared with the original image. In addition, the entropy value used in the objective criterion reveals the finer details present in the image.

The objective function is expressed as follows:

$$F(I_e) = \log(\log(E(I_S))) \times \frac{n\_edgels(I_S)}{M \times N} \times H(I_{ge}) \tag{5}$$

where I_{ge} is the gray-level enhanced image produced by the proposed enhancement algorithm. The edges or edgels of Eqn. (5) are determined by using Sobel edge detector. Following the Sobel edge operator, the edge image I_S is obtained for the enhanced gray image. $E(I_S)$ represent the sum of M × N pixel intensities of Sobel edge image I_S n_edgels indicates the number of pixels, whose intensity values is higher than a threshold in the Sobel edge image. Based on the histogram, the entropy value is calculated on the enhanced image as given by Eqn. (6)

$$H(I_e) = -\sum_{i=0}^{255} e_i \tag{6}$$

Where $e_i = h_i \log_2 h_i$, if hi $\neq$ 0 otherwise ei = 0. The hi is the probability occurrence of i th intensity value of enhanced gray image Ige.

IV. Experimental Results And Discussions

This section presents the experimental results of the proposed

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method Optimized LCM-CLAHE. In this paper, the most popular image enhancement techniques like HE, USM and CLAHE techniques are chosen in order to validate the proposed technique. The Local Contrast Enhancement in the LCM-CLAHE method preserves the local information. Determining the optimum contrast enhancement without losing fine details is a very big challenge in mammogram contrast enhancement. Using the Optimization technique we are getting an optimal contrast enhancement for mammogram images as shown in Table I.

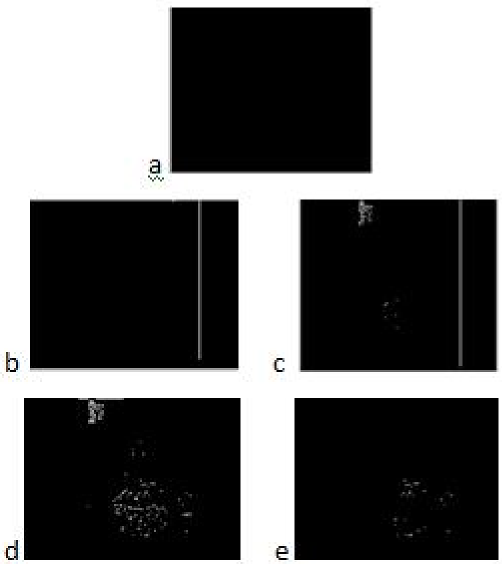

Fig. 2. Response of Sobel operator (a) Original image (b) Histogram Equalization (c) Unsharp masking (d) CLAHE (e) Proposed method

The above figure shows the sobel operator response for original image, Histogram Equalization, Unsharp masking, CLAHE and Proposed method for threshold 0.15.

TABLE I. COMPARISON OF PSNR VALUES PRODUCED BY HE, USM, CLAHE AND PROPOSED METHOD LCM-CLAHE

Image	PSNR			
	HE	USM	CLAHE	LCM-CLAHE
mdb005	33.04	32.89	55.67	**45.23**
mdb006	32.89	31.56	53.54	**43.47**
mdb007	30.45	36.43	51.09	**42.21**
mdb010	33.46	35.67	53.78	**44.57**
mdb011	36.66	34.12	51.36	**41.49**
mdb012	33.9	29.45	50.55	**40.08**
mdb017	29.94	30.48	54.11	**45.10**
mdb019	31.77	32.33	53.48	**42.54**
mdb023	32.69	30.32	52.31	**41.67**
mdb025	29.56	35.88	55.68	**46.59**
mdb086	30.68	31.90	53.39	**41.22**
mdb090	31.76	32.19	54.01	**45.89**
mdb213	29.68	35.15	53.68	**44.17**
mdb238	30.71	35.52	50.71	**41.65**
mdb076	31.01	34.58	55.34	**43.67**
mdb086	29.31	35.46	51.41	**44.88**
mdb201	34.78	30.10	50.68	**43.85**
mdb202	34.84	32.01	52.59	**42.73**
mdb218	33.04	34.00	55.04	**44.90**
mdb214	29.08	35.71	51.17	**45.66**
mdb220	33.52	32.91	50.20	**45.89**
mdb235	29.59	35.41	50.55	**41.71**
mdb239	34	31.75	53.28	**43.53**
mdb242	29.50	34.84	55.20	**47.80**
mdb243	31.26	33.74	52.99	**45.75**
mdb244	31.66	32.90	51.74	**42.81**
mdb249	31.34	33.35	52.79	**46.84**
mdb254	34.16	32.68	55.97	**43.74**
mdb280	47.23	29.11	55.73	**45.86**

V. PERFORMANCE MEASURE

An image is said to be enhanced if it allows the viewer to better perceive the desirable information in the image. The performance measure used here is Peak Signal to Noise Ratio (PSNR) [20]. The PSNR value of an image G with respect to the original image F, both of size M×N pixels, is calculated as shown below

$$M_s = \sum_{m,n} \left[F(m,n) - G(m,n)\right]^2 \qquad (7)$$

$$PSNR = 10 * \log_{10} \frac{255^2}{M_s} \qquad (8)$$

Where Ms is the mean Squared Error given by Equation(7)

The Table I shows the quantitative performance measure for all 29 numbers of abnormal MIAS mammogram images. When the value of PSNR is too high, it indicates over enhancement in the output image and it shows a loss of local information or it may leads to insufficient medical details during diagnosis. And a very low value of PSNR indicates hidden information is not enhanced properly. So for proper contrast enhancement without losing the local information an optimal value of PSNR is necessary. From experimental result, it is clear that LCM-CLAHE gives optimal level of enhancement (PSNR=41.71) without losing the finer information of original image where as for Unsharp Masking (PSNR=35.41), HE (PSNR=29.59) is not enhanced properly and CLAHE (PSNR=50.55) which shows over enhancement for image mdb235. The above discussion is also conformed when the enhanced images are tested by sobel edge detection method. The results of sobel operator are shown in the figure 2. The threshold of sobel operator is fixed at 0.15 for better results. The sobel operator gives very poor response for input image due to very low contrast. And for HE, Unsharp Masking and CLAHE also it is not showing good results. Results for HE and Unsharp Masking shows information washed out and CLAHE introduces artifacts. But the proposed method gives neither optimal response neither the information washed out nor artifacts. The final result of proposed method is shown in figure 3 and figure 4. From both figures it is

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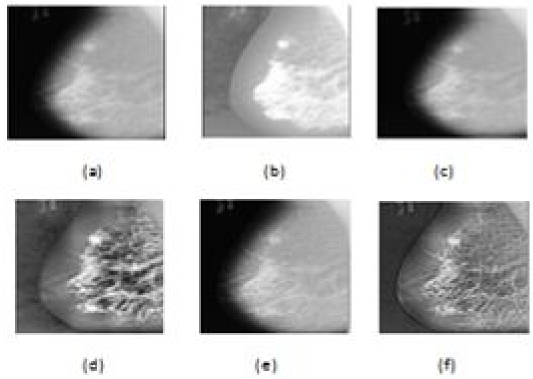

Fig. 3. Enhancement results for fatty mammogram image (mdb023) (a) original mammogram image (b) Image Enhancement using Histogram Equalization (c) Image Enhancement using USM (d) Image Enhancement using CLAHE (e) LCM Enhanced Image (f) Proposed method

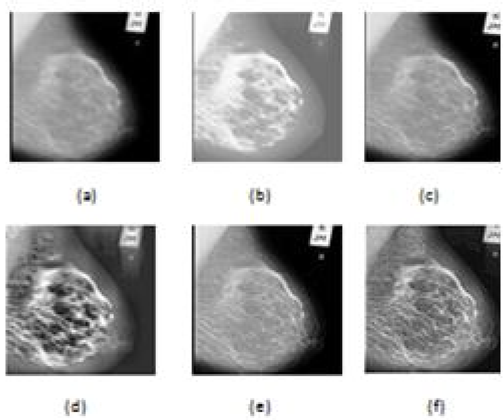

Fig. 3. Enhancement results for fatty mammogram image (mdb020) (a) original mammogram image (b) Image Enhancement using Histogram Equalization (c) Image Enhancement using USM (d) Image Enhancement using CLAHE (e) LCM Enhanced Image (f) Proposed method

clearly visible that proposed method gives optimal result when compared with other methods like HE, Unsharp Masking and CLAHE.

Conclusion

In this paper we have proposed an optimized enhancement technique called Contrast Limited Adaptive Histogram Equalization based on Local Contrast Modification to enhance the finer details of mammogram images and an optimization technique for tuning the enhancement parameter. The proposed method provides optimum contrast enhancement while preserving the local information of the input mammogram image. In our proposed method the most important property is that it can produce better results with proper tuning of parameter. But in case of Standard Histogram Equalization, Unsharpmasking and Normal CLAHE it produces only one enhanced image for a particular input image.

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